ICE BREAKUP RECONNAISSANCE

Ice strength categories range from rotten, dark, candled, weak ice to hard, blue-green, strong ice, and are qualitatively assessed. Other observations include ice characteristics such as the degree of fracturing and ice movement. Water levels are also assessed by estimating freeboard to flood levels at villages or feet below bankfull level, area and depth of overbank water, and rising or falling tendency.

BREAKUP OBSERVATIONS

Ice conditions prior to and in early stages of breakup

Following the initial snowmelt period and initiation of ice decay, further snowmelt at low elevations in the basin will cause runoff to flow onto the ice. Some of this runoff will pond on top of the ice, while the remainder drains into the river channel through holes or cracks in the ice sheet. Strength categories range from rotten, dark, candled, weak ice (see image) to hard, blue-green, strong ice, and are qualitatively assessed. Rotten ice often forms a condition called candled ice (see image). Continued increasing flow in the channel will generate increasing pressure on the underside of the ice. An early indication of this increased pressure is arching (see image), where the central portion of the ice sheet is lifted while the edges of the sheet remain firmly attached to the banks; ponded runoff will concentrate in channels along the banks while the center of the ice sheet is dry.

Additional pressure on the underside of the ice due to increasing flow and weakening of the ice near the edges will cause 1) the ice that is frozen to the banks to break free or 2) the ice sheet to break away from the bank ice. The ice sheet will float on the rising water levels. Since water levels during the fall freezeup period are typically low, rising water levels in the spring will result in a wider channel with a relatively narrow strip of main channel ice floating above the deeper portion of the channel. Further weakening of the ice and continued force of the river current on the sheet will eventually cause the ice sheet to fracture along the banks, float on the rising water level (lifting) (see image), and shift in the open water (see image), resulting in the first movement of the ice. Most observers would record this shifting as the date of first ice movement. At locations with ice breakup contests that are terminated by the movement of a tripod on the ice, this first movement may be sufficient to end the contest and be called "breakup" even though ice sheets still remain in front of the town.

It is not uncommon for the channel to be sufficiently wide that ice sheets break apart, turn sideways in the channel, and drift downstream to accumulate some distance away. An observer on the ground would likely conclude that the ice had broken up and that boating was possible on the river, even though the major breakup activity had not yet begun. Local residents often begin boating within the open reach of river at this stage of the breakup process. Even if this local shifting has taken place, the primary breakup process that holds the greatest threat of flooding has not yet passed this location.

Moving ice characteristics

The primary breakup process often begins in the upper reaches of the river, although intermediate breakup fronts may be initiated at other points along the river. Movement of the ice sheets is initiated when increased flow in the river and increased local stream gradient due to the resistance of the ice sheets floating on the surface combine to increase the drag on the ice sheet to a level sufficient to overcome the forces holding the ice in place. The moving ice sheets reduce in size primarily by physical impact, although ice continues to melt as it moves downstream. Ice sheets break into smaller ice pans. Pans impacting other pans break apart to reduce the size to chunks.

The breakup front is the interface between stationary and moving ice sheets. Upstream of the breakup front is typically 1) a reach of large moving sheets, 2) a reach of mixed broken sheets, large and small pans (see image), and chunks, and 3) a reach of mostly chunks (see image). The total length of moving ice upstream of the breakup front can be many miles, especially on large rivers such as the Yukon River, where a run of ice 10 to 20 miles long is not uncommon.

Ice jam formation and release -

When the breakup front meets strong ice, the moving ice stops at this jam point. The ice stoppage continues in the upstream direction. The severity of the water level rise associated with the ice stoppage is directly related to the flow velocity under the ice cover (Beltaos, 1990). Other causes for ice jamming include a bend in the river (see image), a bend and constriction in the river (see image), a constriction in the river channel (see image), an island or gravel bar, or other obstructions. If a jam forms in one channel of a multi-channel reach (see image), flooding is not likely as long as the other channels continue to run.

In years that have low discharges during breakup, it has been observed that the ice run behind the breakup front loses momentum such that very weak ice may be sufficient to cause the ice to stop running. The resulting jam is a surface jam, where ice accumulates on the surface upstream of the jam point. Water levels upstream of such jams increase due to the stopped ice that increases the hydraulic resistance in the channel. Only minor flooding of upstream villages is typical associated with this type of jam. Once the head on the jam builds sufficiently to initiate movement, the breakup front again progresses downstream.

In years with greater runoff, the discharge and velocity will be larger. Stronger ice is required to stop the breakup front during these years. When the ice stops, chunk ice from upstream often submerges under the stopped ice to form a thickened jam or hanging dam. Water levels upstream of such jams increase rapidly and often cause major flooding in upstream villages (see image). Flooding can occur to towns within the reach of jammed ice (see image) or miles upstream of the jammed ice (see image). Overbank flooding has been observed to extend for many miles away from the river (see image). along certain reaches of the Yukon River.

The field team estimates the depth of overbank water and the head of water backed up by the ice jam. The release of the jam is similar to a dam break, and the increase in stage downstream, excluding ice resistance affects, is estimated to be one half of the head on the jam. The effects of the ice will often cause t he water level to be greater and water levels may remain at near bankfull levels in the vicinity of the breakup front many miles down river. Beltaos (1990) presents equations for the surge celerity and the surging water velocity following the release of an ice jam. Observations of surge celerity ranging from 15 to 20 mph following ice jam releases during the 1994 breakup confirm the relatively high surge celerity values that would be computed using the Beltaos equations. Several ice jams in 1994 held for extended periods, during which downstream ice had the chance to rot enough that the surge initiated ice movement. Surge celerity was estimated from calculating the rate of movement of the breakup front. In some years, strong ice downstream would resist movement by the surge; the surge would pass beneath the ice making the celerity difficult to observe and compute.

REFERENCE CITED

Beltaos, S. 1990. Breakup Jams. In Cold Regions Hydrology and Hydraulics. Ryan, W.L. and R.D. Crissman, Eds. Published by American Society of Civil Engineers, pp 485-515.